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THE INCIDENCE OF VESTIBULAR SYMPTOMATOLOGY IN 2,500 U.S. NAVY DIVING ACCIDENTS (1933-1970)

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ABSTRACT

The U.S. Navy diving accident records (2,500 cases) for the years 1933 to 1970 were analyzed and sorted into Type I and Type II decompression sickness. Type II was further sorted into "vestibular" and "other" categories. It was concluded that Type II symptoms accounted for 30% of the decompression accidents and it was estimated that the overall incidence of vestibular symptomatology was between 10 and 20%. Nearly 30% of the Type II cases were diagnosed as having vestibular involvement, although almost 60% of the cases contained a report of a symptom typically associated with the vestibular system complex (e.g., dizziness and nausea).

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10. Vision						
11. Hearing						
12. Joint pain						

CONTENTS

THE INCIDENCE OF VESTIBULAR SYMPTOMATOLOGY* IN 2,500 U.S. NAVY DIVING ACCIDENTS (1933-1970)

Robert S. Kennedy** and Joseph A. Diachenko***

INTRODUCTION

Decompression sickness (DCS) has always been one of the main occupational hazards of divers and tunnel workers. The most frequently reported symptom, joint pain, is considered the chief symptom of the malady, and occasionally a diagnosis of DCS will not be made unless joint pain is present. Furthermore, while U.S. Navy diving tables are predicated on the theory of the solubility of gases, they have also been empirically validated against a criterion of freedom from symptoms, particularly freedom from joint pain. Historically, however, in addition to pain, other symptoms have been shown to occur in connection with decompression sickness, and many of these symptoms are generally considered to reflect central nervous system involvement. One of these symptoms (vertigo) generally indicates involvement of the vestibular apparatus, its neural pathways or central projections.

A recent annotated bibliography of vestibular problems in diving[7] revealed that, particularly among the earlier writers, after joint pain,

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ear problems were the next most frequently mentioned symptom complexes. A review of this work is available.[8] Rubenstein and Summitt,[13] in a review of ten years of Navy diving accidents, showed that even by using a conservative criterion of vestibular involvement (i.e., vertigo, as opposed to all vestibular symptoms) the proportion of vestibular embarassment was increasing in their recent diving experiences.

Since it is known clinically that other symptoms can also result from vestibular involvement, perhaps a review of Navy diving accidents with the intention of including these other symptoms would be advisable. Because so much attention has been paid to joint pain in connection with decompression sickness, and because symptoms other than vertigo (but normally associated with vestibular stimulation) were not considered together in previous epidemiologic reports,[6,12,3,4] it was hypothesized that involvment of the vestibular system was previously underestimated.

The purpose of this study is to report in a general way the incidence of vestibular involvement in Navy diving accidents. A more complete and speculative coverage of these data, including relationships between constitutional factors and type of decompression sickness, as well as selected case histories, will appear later.[1,2,10]

METHOD AND PROCEDURE

A total of 2,502 diving accidents logged by the U.S. Navy between 1933 and 1970 were individually read by one of the authors to obtain an outline of each case showing: diver age, height, weight, depth, bottom time, equipment, gas, and type of accident. The symptoms of DCS were studied to identify each case as a Type I or Type II hit according to

the classification system of Golding, Griffiths, Hempleman, Paton, and Walder[5] where:

Type I = pain, skin rash, or local lymphatic occlusion;

Type II = dizziness, confusion, disorientation, nystagmus, visual signs (diplopia, tunnel vision, et cetera), sensory impairment (paraesthesia, numbness), motor weakness or loss, nausea, dyspnea, and other central nervous system involvements.

Those cases identified as Type II were further sorted regarding the incidence of symptoms typically manifested by vestibular embarassment: dizziness, vertigo, nausea, nystagmus, disequilibrium, certain visual phenomena, acoustic aura, and disorientation. The following criteria were employed to clarify a Type II case as having vestibular involvement:

1. Diagnosis of presiding medical officer as a labyrinthine problem, inner ear or middle ear embolism, vestibular hit, et cetera.

2. A combination of symptoms such as dizziness and nausea with disequilibrium, nystagmus, and visual or acoustic aura with gait problems, et cetera.

3. Dizziness and nausea with supportive reporting in the narrative to warrant a reasonable assumption of vestibular involvement, such as persistent dizziness during treatment, precipitated by changes in body position (positional vertigo).

4. Vertigo.

RESULTS

A total of 2,502 case reports were reviewed and these data appear as Table 1. Cases reported between 1933 and 1944 were dropped because it was felt that record keeping was imperfect during the early stages of diving recording from the standpoint of their use in establishing base rate data. This left 2,349 cases, or roughly 100/year between 1945 and 1970. Of these, about one-fourth were civilian cases and these too were dropped since it was felt they were not representative of U.S. Navy diving accidents. They are of some interest, however, and selected civilian case histories will be reported elsewhere.[1] Cases which were clearly not decompression sickness (e.g., air embolism, equipment problems, barotraumatic otitis media [cf. ref. 8, pp. 4, 12, 14], oxygen toxicity) were also removed from consideration. Thus, a total of 1,530 Navy DCS diving accidents remained. Of these, two-thirds were considered Type I and one-third Type II, a slightly higher percentage than was previously reported.[4]

Table 1 shows that vestibular accidents comprise about 27% of the total Type II accidents, and about 10% of all the DCS accidents.

Table 1

Incidence of Vestibular Decompression Sickness Accidents in Total Number Reviewed

Total Accidents Reviewed	2,502
Less 1933-1944 cases	-153
Total Accidents 1945-1970	2,349
Less Civilian Cases	-470
Total Navy cases 1945-1970	1,879
Less Toxicity and Others (non-DCS)	-349
Total Navy DCS Cases 1945-1970	1,530
Less Type I (pain)	-1,073
Total Type II, Navy 1945-1970	457
Less Non-Vestibular DCS	-333
Total Vestibular DCS, Navy	124

Table 2 shows the relative number of Type I or Type II accidents over the period 1945-1970, with a further breakout of vestibular accidents. Graphically presented in Figure 1 and Figure 2 as proportions, are the data from Table 2.

Table 2

Distribution of Type I, Type II, and Vestibular DCS Cases 1945-1970

	Type II			Type I	Total DCS
Year	Vestibular	Non-Vestibular	Total		
1970	3	16	19	38	57
1969	4	16	20	30	50
1968	7	14	21	58	79
1967	2	11	13	48	61
1966	4	15	19	40	59
1965	9	17	26	18	44
1964	8	18	26	21	47
1963	13	15	28	40	68
1962	5	23	28	24	52
1961	3	23	26	35	61
1960	6	24	30	69	99
1959	2	19	21	65	86
1958	6	10	16	41	57
1957	4	4	8	35	43
1956	8	19	27	69	96
1955	8	7	15	21	36
1954	7	15	22	67	89
1953	5	12	17	33	50
1952	6	9	15	40	55
1951	2	3	5	28	33
1950	2	6	8	33	41
1949	3	8	11	24	35
1948	0	5	5	20	25
1947	1	7	8	42	50
1946	3	9	12	68	80
1945	3	8	11	66	77

Figure 1 shows the overall incidence of vestibular accidents in several ways: (1) the grand mean is about 8% of all DCS accidents for the 26-year period although vestibular embarassment ranges from more than 15% in some years to as low as zero to 2% in others: (2) a running mean (3-year base) and a 5-year mean reflect similar functions, namely, a generally increasing incidence of vestibular problems over the years, with peak percentages during 1960-1965 and then a reversal of this trend.

Figure 2 shows the relationship of Type II DCS to total DCS (i.e., Type I plus Type II). The overall percentage is 30% or a ratio of about 2:1 for Type I to Type II. Over these years the proportion of Type II DCS appeared to be increasing up to 1960-1965 and at times the incidence of Type II symptomatology exceeded Type I reports (viz., in 1962, 1964, and 1965). For the last five years for which data is available (1966-1970), the ratio is more in agreement with the 26-year average (i.e., 2:1 for Type I:Type II).

Table 3 shows the number of times that each symptom category was employed in the 457 Type II cases, as well as the percentage occurrences of each. The most frequently reported vestibular-type symptom was dizziness, which appeared on nearly one-third of the Type II accident forms. The least often reported vestibular symptom was nystagmus. Of the 457 cases, at least one vestibular-type symptom was reported on more than half of the forms (N-268)*. For nonvestibular-type symptom categories

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*This is a liberal criterion for vestibular involvement since it is not always possible to determine with confidence whether dizziness or visual anomalies are due to vestibular or other causes.

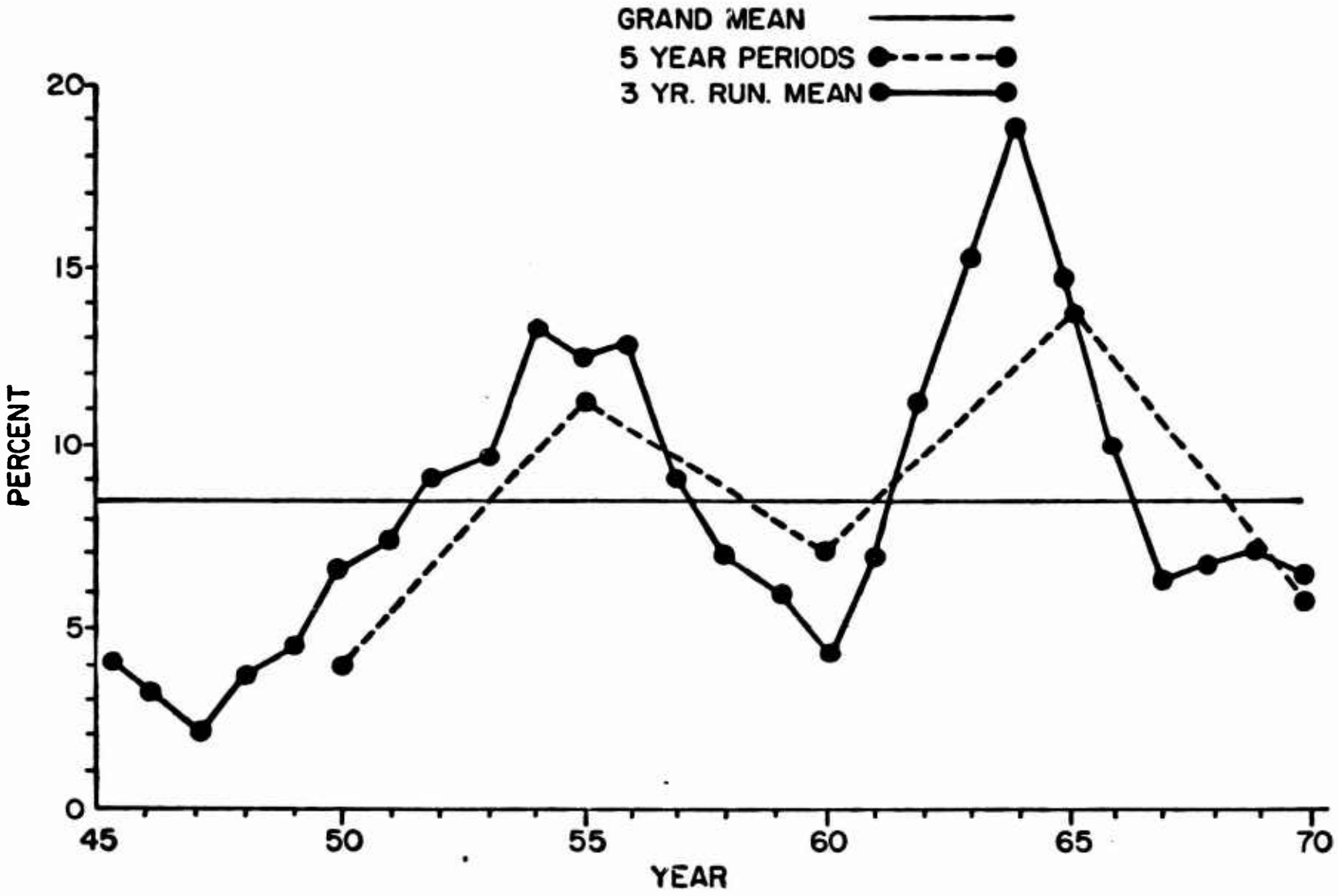

FIG. 1. PROPORTION OF VESTIBULAR D.C.S. TO TOTAL D.C.S. 1945-1970

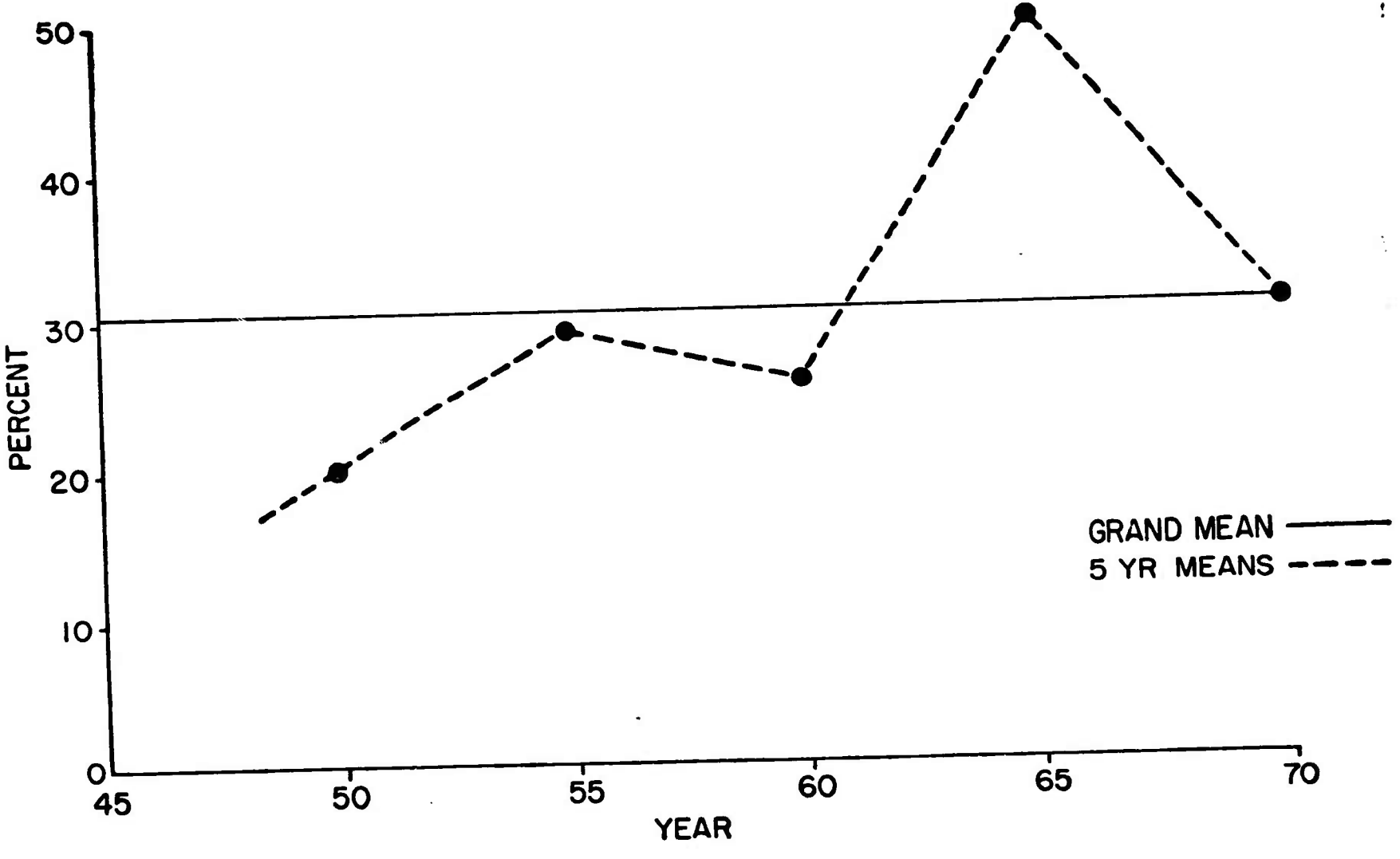

FIG. 2 PROPORTION OF TYPE II D.C.S. TO TOTAL D.C.S. 1945-1970

"weakness, paraesthesia, and numbness" was mentioned most and about as often as dizziness.

Table 3

Summary of Reported Symptomatology for 457 Navy Type II DCS Cases 1945-1970

Symptom	Number* Reporting Symptom	Percentage Occurrence
Dizzy	141	30%
Vertigo	19	4%
Nausea	111	24%
Nystagmus	11	2%
Disequilibrium	15	3%
Hearing	32	7%
Vision	97	21%
Disorientation	19	6%
1 or More Vestibular	268	59%
Non-Vestibular	189	41%

* N = 457

Table 4 summarizes in compact form the incidence of the diagnostic classifications listed variously above, and the relative incidences appear in matrix form. It may be seen that vestibular involvement makes up 9% of the total DCS and 28% of the Type II. Noteworthy, however, is the fact that when a liberal criterion is employed regarding vestibular involvement (i.e., any vestibular-type symptom reported), then vestibular incidence doubles with respect to the total DCS as well as to Type II DCS. The proportion of Type II DCS to the total is shown to be 33%.

Table 4.

A Comparison of Absolute (number) and Relative (proportions) Incidences of Various Diagnostic Categories of Decompression Sickness

	No. of Cases	Proportions 1	2	3	4
1. Vestibular DCS	124	x	46%†	27%	8%
2. Potential Vestibular*	268	x	x	59%	18%
3. Total Type II DCS	457	x	x	x	30%
4. Total DCS	1,530	x	x	x	x

* Any one or more vestibular type symptoms reported.

† Proportion of 1:2 = $\frac{124}{268}$ = 46%

DISCUSSION

The data reported here suggest that the overall incidence of vestibular decompression sickness is higher than most previous reports indicated, being between 10-20% depending on whether a conservative or liberal criterion is employed. Additionally, the incidence of central nervous system forms of decompression sickness (33%) also appear to be somewhat higher than has been reported by others. The higher proportions found in this study are due partly to the fact that they were specifically selected for study and so the authors were poised to see these relationships when they occurred. Additionally, it is felt that another reason for the higher incidences reported is that the entire narrative was read for each form, rather than just a tally of the reported symptoms. Often, localised pain was the only symptom checked on the form; however, other symptoms were described in the text by the diving medical officer. For

this reason, it is felt that the data reported here probably do not overstate the case--indeed, it is probable that the incidence may be even higher for the following reasons:

1. In compressed gas work, dizziness, nausea, vertigo and vomiting, and occasionally ataxia, are considered as vestibular symptoms although only vertigo is generally discussed. However, other symptoms also occur from stimulation to the vestibular system. These include drowsiness, pallor, sweating, salivation, as well as various sorts of visual phenomena (e.g., nystagmus, apparent movement) and should be considered in studying vestibular involvement.

2. Central nervous system (CNS) symptoms, when they develop, are less tangible than pain and may be ignored, not considered manly, or partly controlled (e.g., keeping the head still may minimize vertigo). Thus a person who may present with pain and respond to treatment may have had CNS symptoms earlier, which are missed later during the treatment of the pain.

3. Most of the diver accident records previously used by the U.S. Navy contained physically a broad space in which to record pain-type symptoms, thus the physician is encouraged by the layout of the form to add descriptive comments for pain on the form beside the time it occurred. However, he is enjoined from doing this for vestibular-type symptoms since the space beside dizziness, vertigo, et cetera are blackened out.

4. There may be a tendency to consider Type I and Type II symptoms of DCS as mutually exclusive categories (See McCallum[11] for a review of DCS studies reported between 1914-1966). Therefore, if a person reported

severe pain and mild dizziness, there might be a tendency to classify this as Type I. Further, the tangibility of the pain-type symptoms, with probable higher cure rate, may also cause it to be favored as a diagnostic category.

5. Provocative tests of Eustachian tube clearing at 50 pounds per square inch are conducted prior to Navy diver training,[14] but not necessarily prior to civilian Scuba training. If Eustachian tube patency is negatively related to a susceptibility to vertigo, then other things being equal, data from Navy diver records may underestimate the problem when generalized to include the potential incidence of vestibular problems in all diving.

6. Because a form of apparent movement is experienced less by alcholics[16] and because a "fullness of habit" (Van Rensselaer[15] and others) is common in compressed air workers, then perhaps experiences of vertigo in career divers may be less in these groups than in sport divers.* Other reasons are suggested in Kennedy.[8]

In summary, it is felt that the incidence of vestibular embarassment in U.S. Navy compressed gas work is higher than was previously realized. Moreover, it is likely to have been higher than is reported here. It should be noted that this, plus other factors, suggest that an even higher incidence may occur in civilian diving accidents.

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*This factor may be a training or natural selection variable since a high fluid exchange rate may be a consequence of "fullness of habit." But--a high fluid exchange rate has also been shown to afford some protection from decompression sickness (Warwick[17,18]).

An additional finding of interest emerged from this study regarding diver accident reporting procedures. Since the total population of dives conducted during the 1945-1970 period remains unknown, the incidence of vestibular involvement reported here is only an approximation. True incidence will soon be measurable through the use of the new computer-compatible, dive-log accident form in use since 1970.

However, in regard to the new reporting form it must be pointed out that while the new form offers a significant improvement over the old DD Form 816, the improvement is entirely on the side of easier access to quantified data. Qualitative, narrative reporting is no more encouraged than on the old form. Reporting the sequence and character of symptomatology offers a wealth of information that is lost in the process of listing symptoms out of context, and the new form presents a formidable task of check-list itemizing with only a little space, and no emphasis on the importance of a chronological narrative.

REFERENCES

1. Diachenko, J. A. Civilian diving accidents treated by the U.S. Navy, 1945-1970. In preparation.

2. Diachenko, J. A., and R. S. Kennedy. The relationship of constitutional factors and age to Type I and Type II decompression illness. In preparation.

3. Doll, R. E. Decompression sickness among U.S. Navy operational divers: An estimate of incidence using decompression tables. U.S. Navy Experimental Diving Unit, Wash., D.C., Report No. 4-64, February, 1965.

4. Doll, R. E., and T. E. Berghage. Interrelationships of several parameters of decompression sickness. U.S. Navy Experimental Diving Unit, Wash., D.C., Report No. 7-65, March 1967.

5. Golding, F. C., P. D. Griffiths, H. V. Hempleman, W. D. M. Paton, and D. N. Walder. Decompression sickness during construction of the Dartford Tunnel. Br. J. Ind. Med. 17:167-180, 1960.

6. Keays, F. L. Compressed air illness with a report of 3,692 cases. Cornell University Medical College, Ithaca, New York. Researches from the Department of Medicine, October 1909.

7. Kennedy, R. S. A bibliography of the role of the vestibular apparatus under water and pressure: Content-oriented and annotated. Naval Medical Research Institute Report No. 1, M4306.03.5000BAK9, Bethesda, Md., August 1972.

8. Kennedy, R. S. The role of the vestibular apparatus under water and high pressure. Naval Medical Research Institute Report No. 3, M4306.03.5000BAK9, Bethesda, Md., March 1973a.

9. Kennedy, R. S. General history of vestibular disorders in diving. Naval Medical Research Institute Report No. 4, M4306.03.5000BAK9, Bethesda, Md., December 1973b.

10. Kennedy, R. S., J. A. Diachenko, and M. Sherman. Selected cases of vestibular hits in diving: Character and chronology of symptoms. In preparation.

11. McCallum, R. I. Decompression sickness: A review. Br. J. Ind. Med. 24:4-21, 1968.

12. Rivera, J. C. Decompression sickness among divers: An analysis of 935 cases. U.S. Navy Experimental Diving Unit, Wash., D.C., Report No. 1-63, February 1963.

13. Rubenstein, C. J., and J. K. Summitt. Vestibular derangment in decompression. In C. J. Lambertsen (Ed.) Underwater physiology. pp. 287-292. New York: Academic Press, 1971.

14. Shilling, C. W. Aero-otitis media and auditory acuity loss in submarine escape training. Trans. Am. Acad. Ophthalmol. Otolaryngol. 49:97-102, 1944-45.

15. Van Rensselaer, H. The pathology of the caisson disease. Trans. N.Y. State Med. Soc. pp. 408-444, 1891.

16. Voth, A. C. Autokinesis and alcoholism. Q. J. Stud. Alcohol 26(3):412-422, 1965.

17. Warwick, O. H. The apparent relationship of fluid balance to the incidence of decompression sickness. No. 2 Clinical Investigation Unit, RCAF, Regina. Report to NRC, April 1942.

18. Warwick, O. H. Further studies on the relationship of fluid intake and output to the incidence of decompression sickness. Flying Personnel Medical Section. No. 1 "Y" Depot, RCAF, Halifax. Report to NRC, February 1943.